Europäisches Patentamt
European Patent Office
Office européen des brevets

(19)

(11) Publication number: **0 258 471 A1**

(12) EUROPEAN PATENT APPLICATION

(21) Application number: 86112071.5

(51) Int. Cl.[4]: G05B 19/18

(22) Date of filing: 01.09.86

(43) Date of publication of application: 09.03.88 Bulletin 88/10

(84) Designated Contracting States: AT CH DE FR GB IT LI NL SE

(71) Applicant: Kakino, Yoshiaki, Dr.
256-5 Hanazono-cho Iwakura
Sakyo-ku Kyoto-shi Kyoto 606(JP)

(72) Inventor: Kakino, Yoshiaki, Dr.
256-5 Hanazono-cho Iwakura
Sakyo-ku Kyoto-shi, Kyoto 606(JP)
Inventor: Ihara, Yukitoshi
F 605, 6-583 Gojoubashi-higashi
Higashiyama ku,Kyoto-city(JP)
Inventor: Kamei, Aketoshi
c/o Tokyo Seimitsu Co., Ltd. 9-7-1
Shimorenjaku
Mitaka-shi, Tokyo 181(JP)

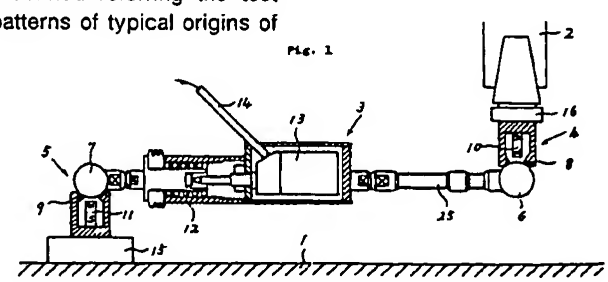
(74) Representative: Weickmann, Heinrich, Dipl.-Ing. et al
Patentanwälte Dipl.-Ing. H.Weickmann
Dipl.-Phys.Dr. K.Fincke Dipl.-Ing.
F.A.Weickmann Dipl.-Chem. B. Huber Dr.-Ing.
H. Liska Dipl.-Phys.Dr. J. Prechtel Postfach
860820
D-8000 München 86(DE)

(54) Method and device to measure motion errors of NC machine tools.

(57) Telescopic movements ΔR of motion errors of NC machine tools, using an axially telescopic bar which has rotary joints at both ends and a built-in scale are measured. One end of the bar is mounted on the spindle of the NC machine tool, the other end on the machine table. One end of the bar takes a circular motion relative to the center of the rotary joint of the other end. The telescopic movement ΔR at each rotational angle is memorized and recorded. Orgins of the errors are defined referring the test result to prepared trace patterns of typical origins of errors.

EP 0 258 471 A1

FIG. 1



Method and device to measure motion errors of NC machine tools.

Applications :

The present invention relates to means to measure the motion errors of NC machine tools accurately and conveniently by detecting the out-of-roundness errors of a circular interpolation motion of NC machine tools having two or more orthogonal axes, and to define the origins of motion errors from the obtained polar plots.

Background of the invention :

A conventional method to measure motion errors of NC machine tools requires to actually machine a plate on the machine tool with a circular interpolation program, and the out-of-roundness errors of the machined plate is measured with an available means such as the out-of-roundness measuring machine, as specified in JIS-B6336. As aforementioned, this method requires two separate operations, machining and measuring, and takes a lot of time also. Besides, the data obtained by this method is not accurate enough for analizing the test results to define the origins of the errors of the machine tool, because the sensitibity of the method is affected by the diameter of the cutting tool to machine a plate, as well as by the ability of available out-of-roundness measuring machine which are unable to make quick responce and the fine movements of actual motions are not precisely detected. In addition to that, the measuring range of this method is restricted by the measuring range of the out-of-roundness measuring machine itself. And, the maximum diameter of the circular plate is about 400mm even for a big machine tool having wide working area, since the capacity of out-of-roundness measuring machines now available is about 400mm in diameter.

Covering up such defects, this invention provides a new method to measure motion errors of NC machine tools and define the origins of the detected errors, by which NC machine tools can be assembled and adjusted in a shorter period of time, as well as the cost of developing a new machine tool is lowered, since geometric errors can be found more easily than before, and modifications can be made at an earlier stage in developing new machines.

Detailed description of a preferred embodiment :

Fig.1 shows measuring members of the measuring device embodying the invention. Steel balls (6) and (7) are mounted on the both ends of a bar (3) which has an axial telescopic mechanism (12) in it. The steel ball (6) constitutes a rotary joint (4) coupled with a spherical socket (8) and a permanent magnet (10) in the spherical socket (8). The magnetic circuit of the permanent magnet (10) forms a closed loop through the spherical socket (8) and the steel ball (6). And, the steel ball (6) is rotatablly maintained in the spherical socket (8) when an appropriate gap is left between the permanent magnet (10) and the steel ball (6). The other steel ball (7) also constitutes a rotary joint (5). The telescopic mechanism (12) is so adjusted to allow the said bar to expand or contract in axial direction only, leaving the smallest possible play in rateral direction. The axial telescopic movement is detected by a displacement detector (13), which sends the signal through an output cable (14) to data processing members. One of well-known devices, such as the moiré scale and the differencial transducer is employed as said displacement detector.

Hereunder, and example of measuring procedures are descrived taking the case of motion error measurements of XY axis table of a vertical type NC milling machine. The rotary joint (4) is mounted on the machine spindle (2) utilizing a chuck (16). The other rotary joint (5) is mounted on the machine table (1) utilizing a fixture (15) at the same level as the rotary joint (4) appart from the steel ball (6) by R0 which represents a normal distance between centers of the steel balls (5) and (6), leaving adequate allowance for the two-way axial movements of the telescopic mechanism. Then, the machine is run by a pre-set program so that the XY table will take a circular interpolation motion around the center of the steel ball (6) with the radius of R0. The machine spindle is not rotated at that time.

If both the motion error of the machine table and the interpolation error of the NC is zero, the bar (3) will rotate around the steel ball (6) with the radius of R0. If and when the motion of the XY table is not accurate, it is not able to make correct circular motion, and the value of R0 changes by ΔR. The displacement ΔR is detected by the displacement detector (13), and the signal is sent to the data processing members through the output cable (14), where the signal is analized.

The hardware of said data processing members is shown in Fig.2. A series of tests have been carried out employing a moiré scale as the detector (13), and the detected signals are digitized and are sent to a microcomputer (19) through an interface unit (18). The obtained data are processed chiefly by said microcomputer (19) which is accompanied by a CRT display (20), a floppy disc memory (21), a key board (22) and a XY plotter (23).

Fig.3 shows a flow chart of data handling process. The signals sent from the detector (13) are digitized by an up-down counter (17). At that time, the normal distance between the two steel balls, R0, shown at the begining of the test is deleted, and only displacements from R0 are counted. The interface (18) is so adjusted that the output signals from the counter (17) are sent to the computer intermittently with a certain degree of rotational angle, every 0.1 degree for example. Though accurate signals of the rotational angle would be taken from the controller of the machine tool, it requires troublesome procedures to do so. On the other hand, NC machine tools on the market employ precise equiangular speed motion to take circular interpolation motion. And, in case of a sampling rate of 0.1 degree or so, it is practically accurate enough to make sampling at intervals of a certain period of time corresponding to the rotational angle. The read data are stored in the data memory (19) and are transferred into the polar coordinate system to make polar plots. The transferred data are shown on the CRT display (20) right away. All data obtained by one full turn of test are stored in the memory, and the deviations and errors in proportion to the datum circle are displayed. Such tests are carried out in one each clockwise and counter-clockwise turn to obtain bi-directional polar plots, and the motion errors of the machine tool are evaluated in total in regard to the below-mentioned items in each XY, YZ and ZX plane :

1. Out-of-roundness errors in clockwise and counter-clockwise circular motions.
2. Uni-directional repeatability errors.
3. Bi-directional repeatability errors.
4. Higher harmonic components. After such total evaluation, characteristics of the measured errors are extracted, taking the following items into consideration :

1. Whether the trace is symmetrical about orthogonal axes.
2. Inclination of the axes.
3. Ellipticity.
4. Height difference and irregularity.
5. Influence of the rotational direction.

Typical patterns of traces are shown in Fig.4, 5, 6 and 7. These typical characteristic patterns of error origins are stored in the data bank (24). Fig.4 represents the characteristic pattern for the extended X axis scale, Fig.5 for periodical errors of the feed mechanism of X axis, Fig.6 for the squareness error between X and Y axes, Fig.7 for the X axis guide way warped up in Z axis direction at its both ends.

Referring the characteristics of the obtained circular trace to such data, the originas of motion errors of the measured machine tool are defined. The following are typical error origins of NC machine tool :

Geometric error :

1. Straightness error of guide way.
2. Squareness error between two axes.
3. Angular motion of the slider.

Potential error of feed mechanism :

4. Uniform error of the positioning scale.
5. Back-rush of feed drive mechansim.
6. Pitch error of the ball screw.
7. Indexing error of the positioning scale.

Kinetic error of feed mechanism :

8. Positioning error caused by overrun.
9. Stick motion and stick slip.
10. Error caused by vibration.
11. Lost motion.
12. Mismatching of position 1oop gain.

In most of actual cases, these error origins are found mixed instead of individually. And, the circular traces obtained by means of this invention also usually show mixed characteristics of several error origins.

The following are descriptions of traces obtained by actual measurements. In Fig.8, the value of ΔR suddenly changes at each point of X_1, X_2, Y_1, and Y_2. At such points, the direction of the movement of the XY table is reversed. The errors are apparently originated from lost motion caused by the table drive mechanism of the machine. The trace of Fig.9 is deviated elliptically, and is inclined against two axes, which suggests the squareness error between X and Y axes. After the error components of the lost motion and the higher harmonic vibration are eliminated, the ellipticity of the trace is 8µm. And, the squareness error between two axes is 8µm per 200mm since the length R0 of the bar employed in said test was 200mm.

Fig.10 shows that Y axis has the straightness error in X axis direction.

In the aforementioned examples, tests have been carried out mainly in XY plane fixing the Z axis. In actual measurements, however, circular motion errors are measured in ZX plane fixing Y axis, and in YZ plane fixing X axis also, and three dimensional motion errors are diagnosed utilizing such data obtained from different planes, to define the error origins.

The length R0 of the bar can be adjusted as required, by changing the extention (25) of Fig.1. And, the whole working area of the large NC machine tool can be measured as accurately as the small machine tool. This method is applicable to the horizontal type machine tool also. In the aforementioned test examples, the rotary joints rotatable in any direction were used. However, the purpose of this invention can be accomplished by employing rotary bearings at the both ends of the bar (3) instead of said joints as shown in Fig.11-(26).

Effects of the Invention :

As descrived with samples in the above, motion errors of NC machine tools can be diagnosed accurately, conveniently and in a short period of time, extracting characteristic patterns from motion error traces obtained by means embodying this invention, with calculating process, if necessary. In addition, the error origins are indicated with figures. The method of the invention is superior to the prior art in this point, too. The invention will bring about not only rationalization of adjustment and inspection in manufacturing NC machine tools, but also improvement in accuracy of newly produced machine tools.

4. Brief description of the accompanying drawings.

Fig.1 : Measuring mechanism embodying the invention.

Fig.2 : Descriptions of data processing members.

Fig.3 : Flow chart showing data handling process.

Fig.4 - 7 : Typical patterns of various error origins.

Fig. 8 - 10 : Actual motion error traces obtained by means embodying this invention.

Fig.11 : Description of a substitutional rotary joint.

Claims

1) Means to measure motion errors of NC machine tools, using an axially telescopic bar which has rotary joints at the both ends and a built-in scale to measure its telescopic movementsΔR. One end of the bar is mounted on the spindle of the NC machine tool, and the other end on the machine table. The machine tool is numerically controlled so that the one end of the bar takes a circular interpolation motion relative to the center of the rotary joint of the other end in any of the working planes of the machine. Then, the telescopic movement ΔR at each rotational angle is memorized and recorded to evaluate and analyse motion errors of the NC machine tool chemcing the pattern and amount of deviation in relate to the datum circle. And, the origins of the errors are defined dreferring the test result to the prepared trace patterns of typical origins of errors.

2) Means to measure motion errors of NC machine tools of claim (1), wherein sampling is made periodically at intervals of certain period of time instead of measuring the rotational angles.

3) Means to measure motion errors of NC machine tools consisting of a telescopic bar having a rotary joint on one end which is mounted on the machine spindle, another rotary joint on the other end which is mounted on the machine table, and a built-in transducer which detects the telescopic movements ΔR of the bar and sends signals, a device to memorize value of ΔR at each rotational angle of the circular interpolation motion of the machine tool and plot it on the polar coordinates, a device to record value of ΔR on the polar coordinates, and means to detect how the curve obtained in the circular interpolation motion deviates from its datum circle to extract distinctive characteristics from the detected curve comparing them with the data of typical orgins for motion errors, and to define and display the origins for the motion errors.

4) Means to measure motion errors of NC machine tools of claim (3), wherein the rotary joint consists of a steel ball fixed on the bar, a spherical socket and a magnet to attract the steel ball.

5) Means to measure motion errors of NC machine tools of claim (3), wherein the rotary joint consists of a rotary bearing.

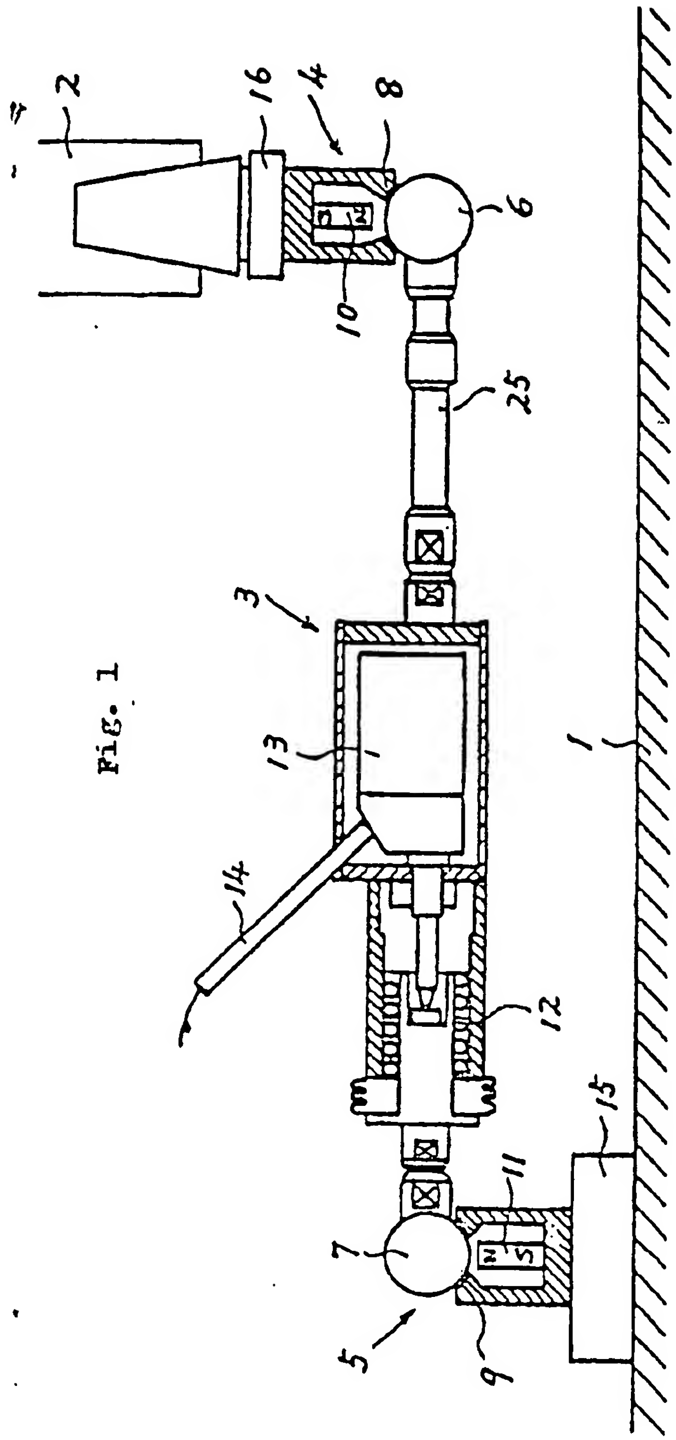


Fig. 1

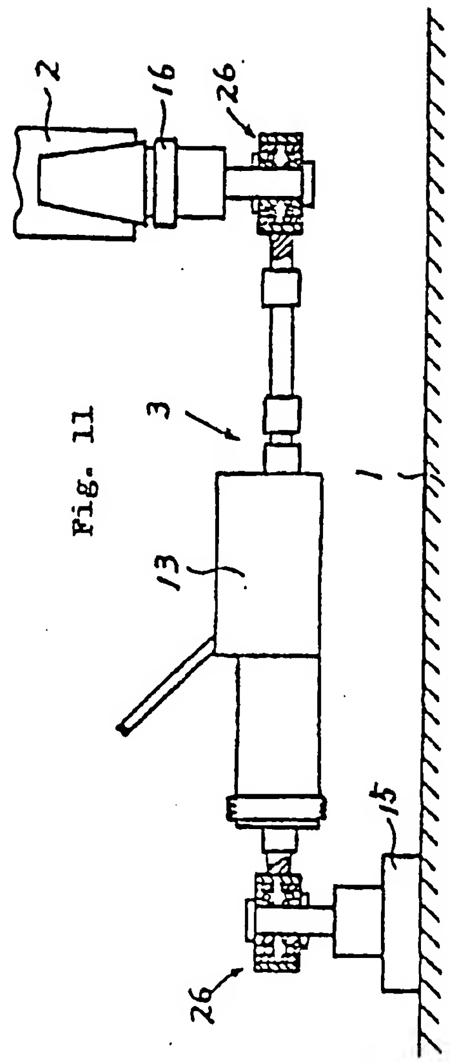


Fig. 11

Fig. 3

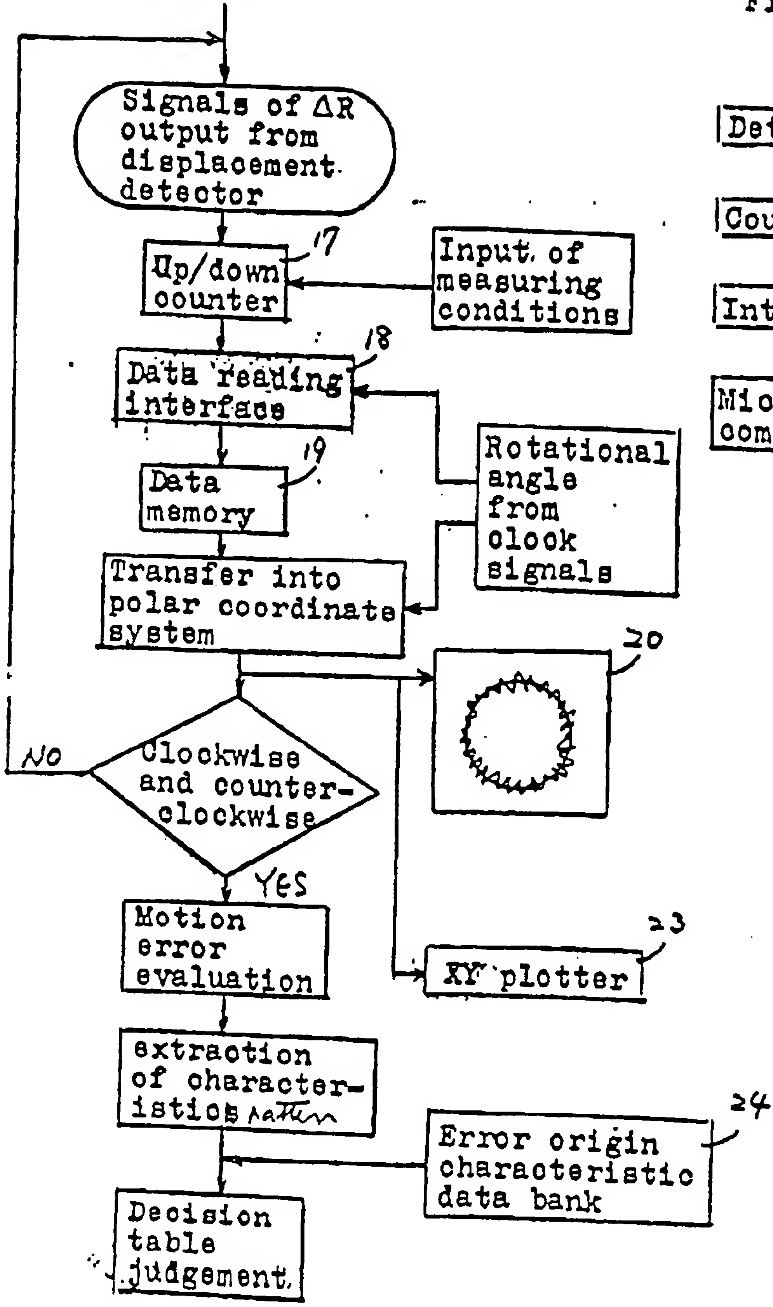

Signals of ΔR output from displacement detector
Up/down counter
17
Input of measuring conditions
Data reading interface
18
Rotational angle from clock signals
Data memory
19
Transfer into polar coordinate system
20
NO
Clockwise and counter-clockwise
YES
Motion error evaluation
XY plotter
23
extraction of characteristics pattern
24
Error origin characteristic data bank
Decision table judgement

Fig. 2

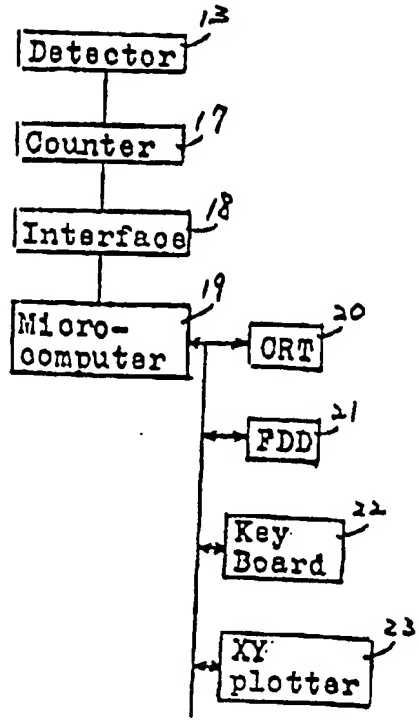

Detector
13
Counter
17
Interface
18
Micro-computer
19
CRT
20
FDD
21
Key Board
22
XY plotter
23

Fig. 4

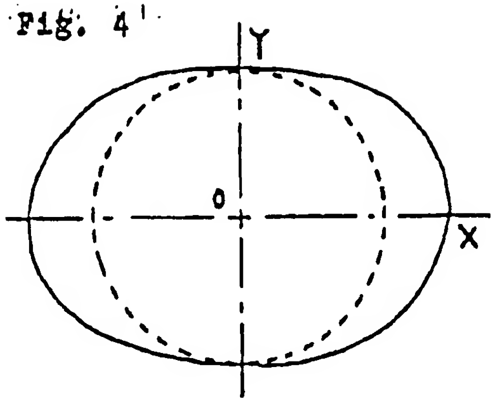


Fig. 6

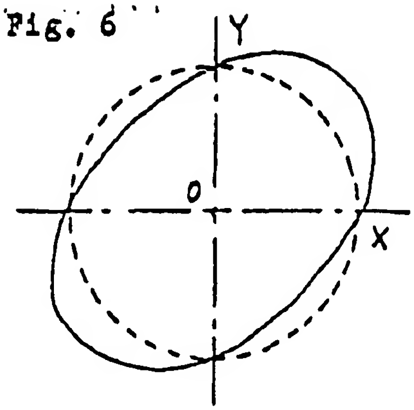


Fig. 5

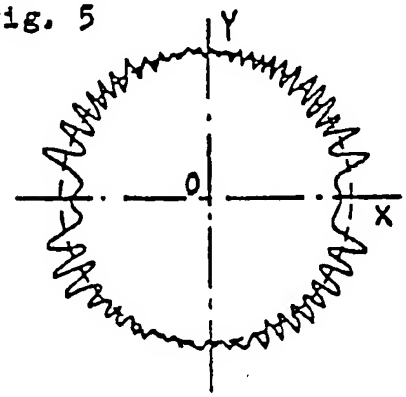


Fig. 7

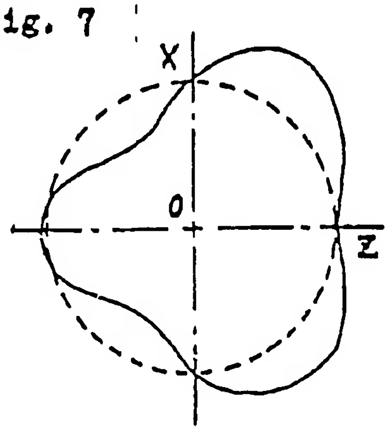


Fig. 8

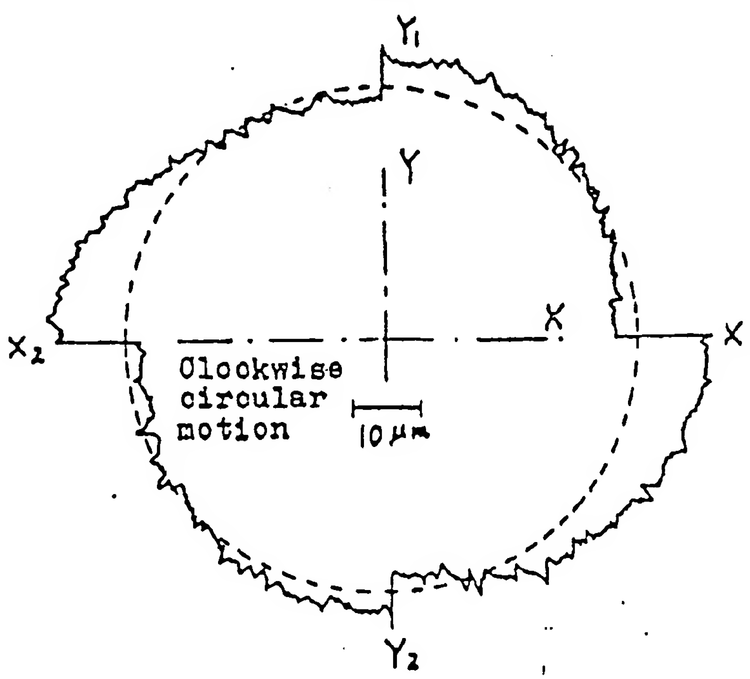


Fig. 9

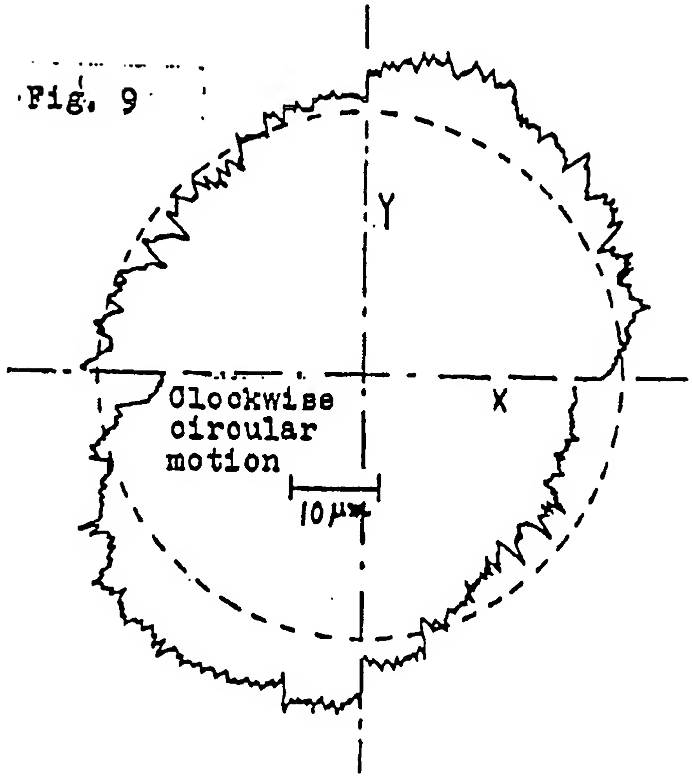
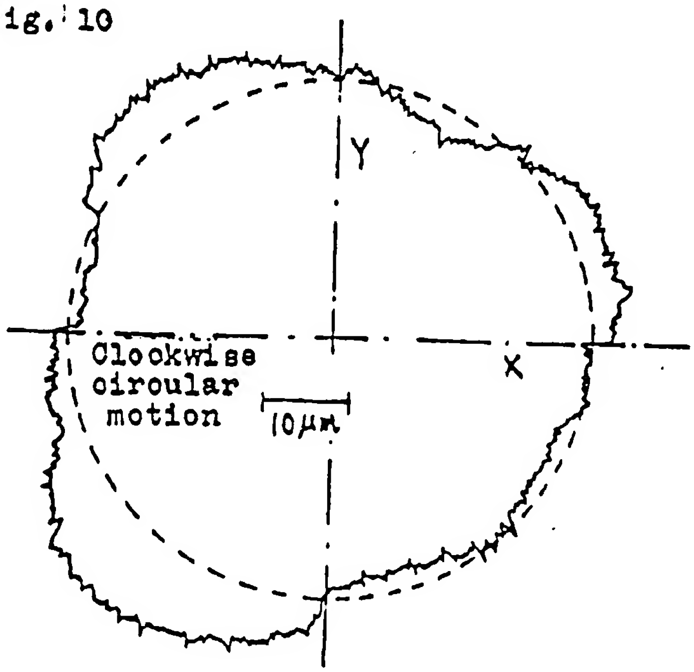

Y
X
Clockwise
circular
motion
10 μm

Fig. 10


Y
X
Clockwise
circular
motion
10 μm

European Patent Office

EUROPEAN SEARCH REPORT

Application number

EP 86 11 2071

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
X	WESTERN ELECTRIC, Technical Digest, no. 20, October 1970, pages 59,60, Princeton, US; W.E. RAPP: "A method for determining response characteristics of a numerically controlled machine" * Whole document *	1,3-5	G 05 B 19/18
Y		2	

Y	GB-A-2 006 481 (N.V. PHILIPS GLOEILAMPENFABRIEKEN) * Abstract; page 4, lines 23-42 *	2	

TECHNICAL FIELDS SEARCHED (Int. Cl.4)

G 05 B
B 23 Q

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	08-04-1987	CORNILLIE O.A.R.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document
T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons
& : member of the same patent family, corresponding document